# Modeling the Effect of Climatic and Human Impacts on Margin Sedimentation

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## LONG-TERM GOALS

Determine if there is a connection between point source or line-source sediment supply and sea level, and whether this connection controls canyon morphology, failure frequency, and gravity flows. Develop robust models of hyperpycnal flow capable of depositing and eroding sediment and interacting with the alongshore current.

## OBJECTIVES

Determine if the formation and intensity of hyperpycnal flows generated at river mouths directly affects the position and formation of submarine canyons. At low seastand, a river can directly deliver sediment near the canyon mouth as a point source. However, during high sea stand hyperpycnal flow generated at river mouths can be an important mechanism of sediment delivery to the continental slope and the canyon.

## APPROACH

a) **Develop a generalized model of hyperpycnal flow** that can be used by Navy and the Scientific Community to simulate the impact of extreme river events on the seafloor morphology. A 2.5D numerical model of hyperpycnal flow has been developed. In this model, the depth-averaged governing equations of dilute suspension and the Exner Equation of bed sediment continuity have been solved using a finite volume technique. The model is based on the earlier work of Bradford and Katopodes (1999) and Imran and Syvitski (2000) on turbidity current. The model *Hyper* simulates the spreading of a hyperpycnal flow and its interaction with the seafloor as well as the alongshore current. The model is robust, efficient, and can be used for non-rectanguar computational domain.

b) **Generate synthetic Flow and Sediment Disacharge at the river mouth** for an extended period using *Hydrotrend*. The hydrologic model developed at INSTAAR has been used to simulate daily sediment loads and water discharge for Po and the smaller Appenine Rivers. It has been found that the Po River is less likely to generate hyperpycnal flow while the smaller Apennine Rivers were capable of generating hyperpycnal flow on a frequent basis. The most significant anthropogenic impact on the river and sediment discharge in the Adriatic has been the construction of dams in the Apennine Rivers. After the dam construction, the Apennine Rivers are still capable of producing hyperpycnal flow but on a much less frequent basis. Results from *Hydrotrend* Model runs made at INSTAAR are utilized here as input conditions for *Hyper*.

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c) **Use a hydrodynamic model that resolves the vertical variation** to simulate the plunging process and convert hydrotrend data into inputs for *Hyper*. The 3-D flow solver *FLUENT* is utilized to convert a sediment-laden flow into a turbidity curent by simulating the plunge process near the river mouth. From *Hydrotrend* runs, flood events that generate large flow and sediment concentration are selected for inflow in *FLUENT* which simulates the conversion of an open channel flow into a density underflow through the plunge process. The use of *FLUENT* provides the bridge between the river flow and a depth-avergaed model of density underflow. An alternative is to use empirical relationships proposed by other researchers which gives a reasonable value of the plunge depth, velocity, and concentration.

d) **Apply *Hyper* to simulate the impact of large floods** on the evolution of seabed morphology. Addintional questions that are to be addressed include what is the effect of alongshore current on the evolution of a spreading hyperpycnal flow, and what role the construction of dams play in altering the effect of large floods on the seabed morphology.

## WORK COMPLETED

The development of a numerical model of hyperpycnal flow incorporating the effect of alongshore current has been completed. The finite volume model is efficient and robust. The code is written in FORTRAN 77 and can be compiled and used in both Windows and Unix environment. The model has been extensively tested for performance and accuracy. The model requires current thickness, velocity, sediment concentration, and grain size at the inflow boundary and simulates the evolution of the current and seabed morphology. Input conditions for model runs can be obtained from *Hydrotrend* model output. *Hydrotrend* model runs have been performed at INSTAAR for the Apennine rivers (e.g., Tronto, Potenza, Pescara, Metauro, Chienti) providing discharge hydrographs for flow and suspended sediment concentration as well as river mouth hydraulics. Typical large flood events under pre and post dam scenario have been selected from these runs and used for deriving input conditions for running *Hyper*. The bathymetry of the seabed has been obtained from navigational charts. Model runs have been performed for Chienti and Potenza and are in progress for the other three rivers. Even though a large flood could last for a day, we considered 8 hours to be a typical flood duration. The computational domain size has been selected to be 10 km ×10 km. A set of run would consist of multiple events of hyperpycnal flow with different flood intensity and alongshore current. In each subsequent event, the bathymetry obtained from the previous run would be used as the initial bed. Table 1 shows input conditions used in *Hyper* simulation obtained from flood flows in the Chienti River.

## RESULTS

Results from some of the numerical simulations are presented here. Figure 1 shows the velocity vector and the current thickness contour at the end of model Run II. The effect of alongshore current and the existing bathymetry is clearly evident. The modest alongshore current has been able to completely turn the current in one direction. The spreading of the current parallel to the shoreline would result in a line source of sediment supply to the continental slope. The effect of the existing bathymetry on the current thickness is also evident from this figure. Figure 2 shows the effect of hyperpycnal flow on the seafloor bathymetry. The initial bathymetry consisted of a relatively steep slope followed by a mild gradient. Variation of the seabed in the alongshore direction has not been considered for the sake of simplicity.

Figure 2(a) shows development of levee-like deposit in the steep near shore area that is followed by a lobe at about 2 km from the shoreline where the seafloor gradient becomes small. Figure 2(b) shows the seafloor elevation at the end of Run II.

***Table 1. Input parameters for model run involving the Chienti River flood flow. Run I : Pre-dam condition without alongshore current; Run II: Pre-dam condition with alongshore current; Run III: Post-dam condition (1 day delay) without alongshore current.***

| Input Parameters | Run I | Run II | Run III | Data Source |
|---|---|---|---|---|
| Computational domain size | 10 km × 10 km | 10 km × 10 km | 10 km × 10 km | |
| Total simulation time | 8 hours | 8 hours | 8 hours | |
| Inflow current thickness | 4.1 m | 4.1 m | 2.96 m | *Hydrotrend Model* |
| Inflow velocity | 1.8 m/s | 1.8 m/s | 1.65 m/s | *Hydrotrend Model* |
| Inflow Sediment concentration | 0.017 $m^3/m^3$ | 0.017 $m^3/m^3$ | 0.0067 $m^3/m^3$ | *Hydrotrend Model* |
| D50 | 30 micron | 30 micron | 30 micron | *Hydrotrend Model* |
| Along-shore current | 0.0 m / s | 0.4 m / s | 0.0 m / s | |

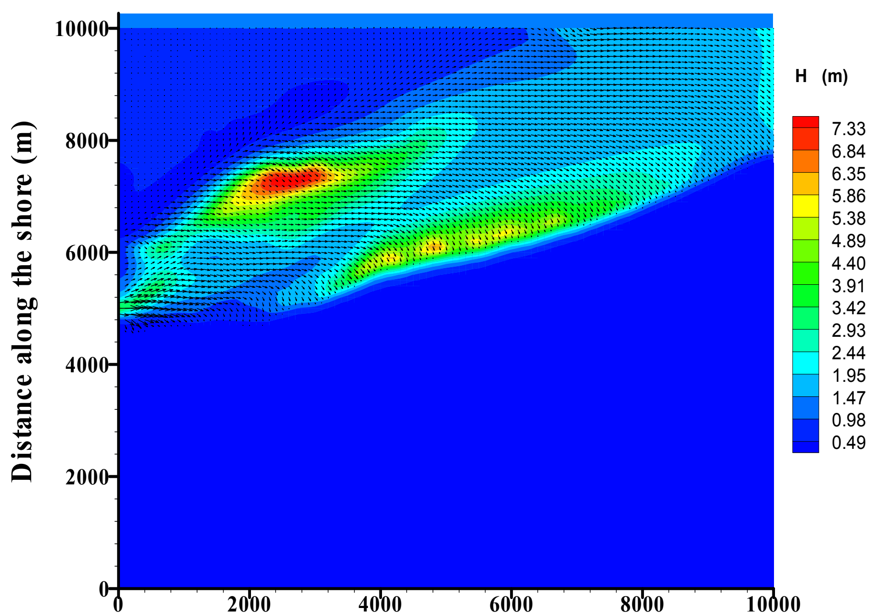


***Figure 1. Velocity vector and current thickness at the completion of Run II listed in Table 1. The flow has been clearly effected by the existing bed deposit from the previous run and became asymmetric due to the presence of the alongshore current.***

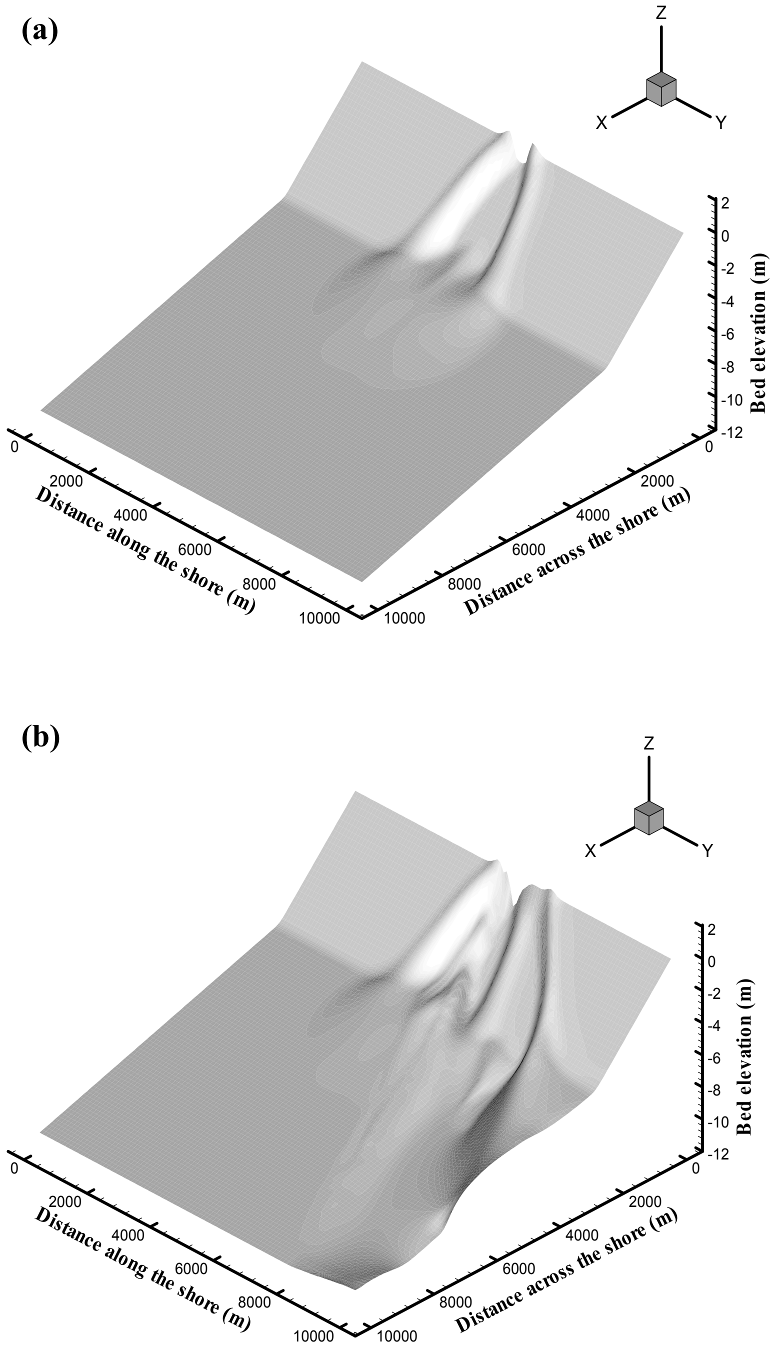


***Figure 2. Simulated bathymetry offshore Chienti River resulted from three simulated hyperpycnal flow events. (a) Pre-dam flood with no alongshore current; (b) Pre-dam flood with alongshore current of 0.4 m/s; (c) post-dam flood without alongshore current. The bathymetry resulting from the previous event is used as the initial bathymetry of the subsequent run.***

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**(c)**

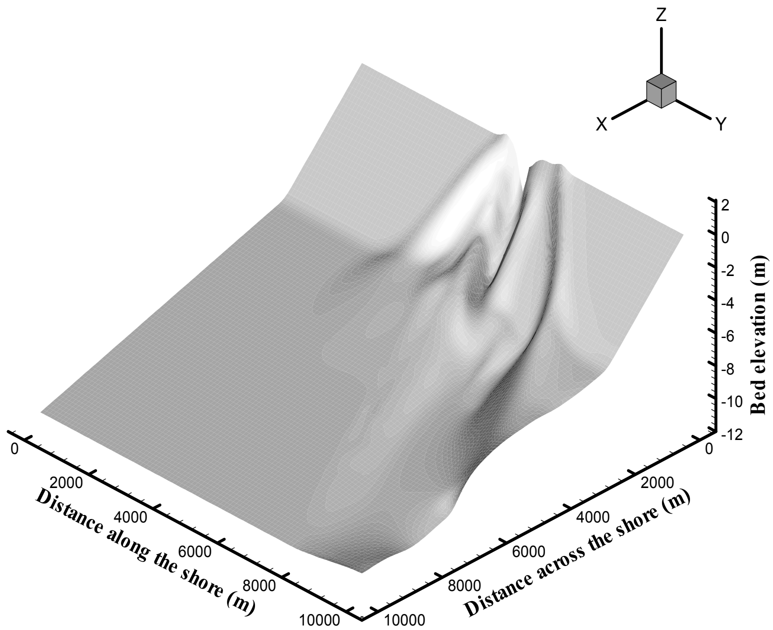


***Figure 2 (Continued).***

***It is clearly seen that the alongshore current has led to a complex crenulated architecture of the sedimentary deposit. The third event (Run III) which is a relatively small flood event further magnifies the complexity of the sediment deposit.***

## IMPACT/APPLICATIONS

The numerical model developed in this research predicts the influence of various forcing on plunging river flow. The effect of alongshore current has been particularly important in shifting the direction of spreading and generating complex bed features. These results may explain sediment waves observed on the seafloor.

## TRANSITIONS

The numerical model is being utilized to study the formation of channel fill and overbank deposit in turbidites. The model will be integrated in the *3-D Sedflux* model of James Syvitski.

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**2.** Syvitski, J. Pratson, L., Wiberg, P., Steckler, M., García, M., Geyer, R., Harris, C., Hutton, E., Imran, J., Lee, H., Morehead, M., Parker, G. Prediction of Margin Stratigraphy. *Continental Margin Sedimentation: Transport to Sequence*, Nittrouer et al. Eds. Blackwell Publ. [refereed special publication, submitted].